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(54) IMPROVEMENTS IN OR RELATING TO VARIABLE LIGHT-BEAM ATTENUATORS

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company, of Berlin and Munich, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to variable light-beam attenuators of a type capable of adjustment to give a continuously variable attenuation of the intensity of a linearly polarised laser beam, in particular for use as a lighting accessory in stage or studio lighting equipment.

A laser beam can have its intensity attenuated by the introduction of a grey filter into the path of the beam. The grey filter generally consists of an absorptive glass or of an absorptive metal layer vaporised onto a glass mounting, but a metal layer type can only be used with laser oscillators of relatively low power. In order to achieve predetermined intensity changes, a set of grey filters may be provided, or better still a grey filter may be used which has an absorption factor that varies considerably, and can be adjusted relative to the beam to give any desired degree of attenuation, within its two limits.

However, this kind of arrangement is cumbersome to use, and is especially unsuitable in the cases where control is required to give lighting that is slowly varying in intensity over a period of time, as in stage lighting, for example.

One object of the present invention is to provide a simple and compact device that can be used for continuously varying the intensity of a laser beam.

The invention consists in a variable light-beam attenuator for use with a linearly polarised laser beam, wherein there is provided a multi-layer polarisation beam splitter mounted to rotate about an axis along which an incident laser beam can be directed; and wherein said layers are disposed at the Brewster angle relative to said axis.

If linearly polarised parallel light having a direction of polarisation parallel to that of the multiple refraction of the beam is incident upon a multi-layer polarisation beam splitter, then the intensity of all the reflected rays will have a minimum value and that of the refracted ray a maximum value. The acutal values differ from the theoretical values of 0 and 1, because the Brewster condition cannot be satisfied at every interface.

During rotation of the arrangement through an angle of 90° about an axis disposed in the direction of the incident beam, the intensity of the refracted ray decreases continuously to finally reach a minimum, whilst the intensity of the reflected rays increases from a minimum to a maximum value.

When using the polarisation beam splitter as a variable attenuator, preferably the transmitted beam component is exploited, and any reflected rays are absorbed by a suitable layer of material covering that area of the beam splitter through which these rays normally emerge, normally on one face of an entry prism that is provided at the end of the device remote from a similar exit prism.

In order to ensure that when the device is rotated for maximum light transmission, the device gives a high transmission intensity, the end faces of the entry and exit prisms are both coated with a non-reflective layer with an optical thickness of $\lambda_o/4$, where λ_o is the wavelength of the incident radiation, these layers being of a material whose refractive index is low compared with the associated prisms.

The invention will now be described with reference to the drawing, which illustrates one exemplary embodiment.

A linearly polarised laser beam 1 produced by a laser (not shown) is incident from a direction A, perpendicularly upon an end face 3 of a glass entry prism 4. The end face 3 has been rendered partially non-reflective by the provision of a magnesium-fluoride layer 5. Both the entry glass prism 4 and an exit glass prism 6 have base angles θ_B of 45°.

[*Price 33p*]

The end face 15 of the glass exit prism 6 is likewise partially demirrored by the provision of an MgF_2-layer 5. On the base surfaces 7 and 8 of each prism a plurality of alternate zinc-sulfide 12 and magnesium fluoride 13 layers, whose refractive indices respectively equal 2.35 and 1.38. The two outermost magnesium fluoride layers are attached together by a cement film 14 with a refractive index n_k. Accordingly the refractive index n_G of the glass is given by the relationship:—

$$n_G = \sqrt{2} \cdot n_{ZnS} \cdot n_{MgF_2} / \sqrt{n^2_{ZnS} + n^2_{MgF_2}}$$

and this equals 1.68 if the light-beam is to satisfy the Brewster condition on refraction at the individual layers. The light-beam is refracted at the indicated interfaces between the glass and first layer and between the neighbouring layers, at the angles θ_G, θ_{ZnS} and θ_{MgF_2}, and leave the system in the direction A′, where θ_G=the angle of incidence of the light-beam at the glass-zinc sulphide interface, θ_{ZnS}=the incidence of the light-beam at the zinc-sulphide magnesium-fluoride interface, and θ_{MgF_2}=the angle of the incidence of the light-beam at the magnesium fluoride-zinc sulphide interface. At each of the interfaces, of course, there is a reflected beam produced, only one of which has been shown, in the direction A″. The directions of the light-beam components reflected at any layer and of the light-beam component refracted in that layer are, in each case, mutually perpendicular.

For stage illumination, with a laser beam 1 coming from the direction A, the exit ray passing in the direction A′ is used, and the rays reflected in the direction A″ are blocked by an absorptive film 9. The cuboid polarisation beam splitter is rotatably mounted within two support rings 10 and 11 to permit rotation about an axis located in the A—A′ direction.

The light-beam emergent in the direction A′ has a maximum intensity for a given angular position of the polarisation beam splitter relative to a polariser (not shown), whilst the rays reflected in the direction A″ at that position have a minimum intensity. If the polarisation beam splitter is now rotated relative to the polariser in a continuous fashion, then the intensity of the ray passing in the direction A′ is continuously reduced to a minimum, whilst the intensity of the ray passing in the direction A″, tends toward a maximum.

In order to fully exploit the ray passing in the direction A′ the thicknesses of the zinc sulphide and magnesium fluoride layers, should be related to the wavelength of the light, and when using an argon ion laser a wavelength of λ_o=500 nm is obtained, and the layer thicknesses d are calculated from the relationships:—

$$d_{ZnS} = (\lambda_o/4)(1/n_{ZnS} \cdot \mathrm{Cos}\,\theta_{ZnS}) \text{ and}$$

$$d_{MgF_2} = (\lambda_o/4)(1/n_{MgF_2} \cdot \mathrm{Cos}\,\theta_{MgF_2});$$

so that d_{ZnS}=61.6 nm., and

d_{MgF_2} = 179 nm., where

$$\theta_{ZnS} = n_{MgF_2}/n_{ZnS} \text{ and } \theta_{MgF_2} = n_{ZnS}/n_{MgF_2}$$

WHAT WE CLAIM IS:—

1. A variable light-beam attenuator for use with a linearly polarised laser beam, wherein there is provided a multi-layer polarisation beam splitter mounted to rotate about an axis along which an incident laser beam can be directed; and wherein said layers are disposed at the Brewster angle relative to said axis.

2. An attenuator as claimed in Claim 1, wherein there is provided a film by which light reflected at the interfaces between said layers is absorbed.

3. An attenuator as claimed in Claim 1 or Claim 2, in which the entry and exit faces have reflection-reducing layers.

4. A variable light-beam attenuator substantially as described with reference to the drawing.

5. A stage or studio lighting source comprising a laser in combination with a variable light-beam attenuator as claimed in any preceding Claim.

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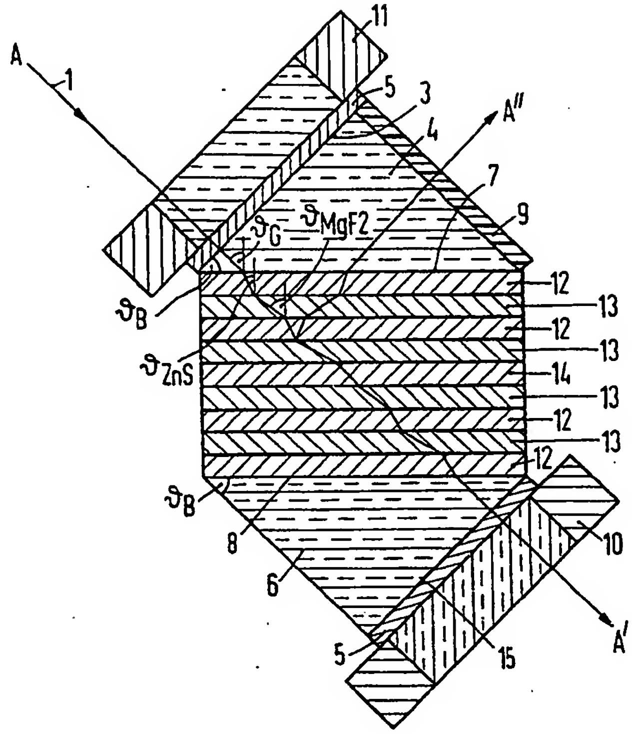
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